THE GRAPHECHON STORAGE TUBE

BY

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by

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PREFACE

The Graphechon storage tube was developed in 1947 at the Princeton Laboratories of the Radio Corporation of America. It was designed to fill the need for a scan conversion and storage tube. The necessity for such a tube arose in the course of development of the Teleran program for air traffic control.

Chapter I of this paper discusses storage tubes in general terms with particular reference to the advantages to be gained from use of the Graphechon. Chapters II and III describe the tube and principles of its operation in some detail. Practical operation and specific characteristics are covered in chapters IV and V.

The months of January through March 1950 were spent by the author at the Radio Corporation of America, R.C.A. Victor Division, Camden, New Jersey. While there every courtesy was freely extended, including the use of an excellent technical library containing much material on this subject not to be found elsewhere. Mr. L. M. Seeburger and Mr. R. C. Bitting were at that time preparing a report on the Graphechon for general distribution and the author assisted them in the verification of data on the performance characteristics of the tube. Their personal friendship and professional knowledge were of untold benefit to the author in this work and he is very grateful to them.

The sound advice of Associate Professor P. E. Cooper of the U. S. Naval Postgraduate School was invaluable in the organization and preparation of this paper.

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CHAPTER I

INTRODUCTION

1. Types of Storage Tubes.

A storage tube is an electron beam vacuum tube into which information is introduced, either by beam modulation or photoemission, and removed at a later time by electronic or visual means. Hereafter the first process is called "writing" and the latter is called "reading". The cathode ray tube as used in an oscilloscope may be thought of as a storage tube in that information is written on by beam deflection, stored during decay time of the phosphor and read off visually.

Electrostatic storage types of electron beam tubes have come into great prominence with the advent of television and high speed electronic computers. The iconoscope (Zworykin, 8) gains its great sensitivity, as compared to the image dissector, in that the charge released by photoemission is stored on the mosaic and used once each scan rather than being collected as it is emitted.

The Memory Tube (Haeff, 13) has three electron beams, a capacitive target coated with a phosphor and an electrically transparent collector screen between target and electron guns. The holding beam is a diffuse electron stream which floods the entire target surface causing it to charge toward one of two stable conditions, either holding beam cathode voltage or collector voltage. The writing beam is used to override the holding beam and determine

which of the two stable voltages a particular spot on the target will assume. A reading beam scans the surface to explore the charge pattern and give an output signal.

The Selectron (Rajchman, 16) uses one electron beam for writing and reading. Information is stored or released by gating a barrier grid structure interposed between electron gun and target. Means for gating the grid wires is provided by bringing numerous leads out through the glass envelope. The Selectron is designed for computing machine application.

The orthicon (Rose, 5) is similar to the iconoscope ~~by~~ but uses a very low velocity scanning beam to yield greater sensitivity. The image orthicon (Rose, 6) uses electron image multiplication, which is obtained by accelerating and focusing the image from a photoconductive surface on a two sided storage target. The target is scanned by a low velocity beam and the signal amplified in an electron multiplier within the tube structure.

In general all of these electrostatic storage tubes use one or more of the stable equilibrium points of an insulated target under electron bombardment. These points are, (a) the voltage of the collector electrode when total secondary radiation is greater than unity and is not voltage saturated, (b) cathode potential of the electron beam when primary impact energy is below the first crossover point and (c) the potential of the second crossover point when the field is strong enough to collect all of the secondary electrons. The target usually has extremely high transverse resistance permitting storage of individual

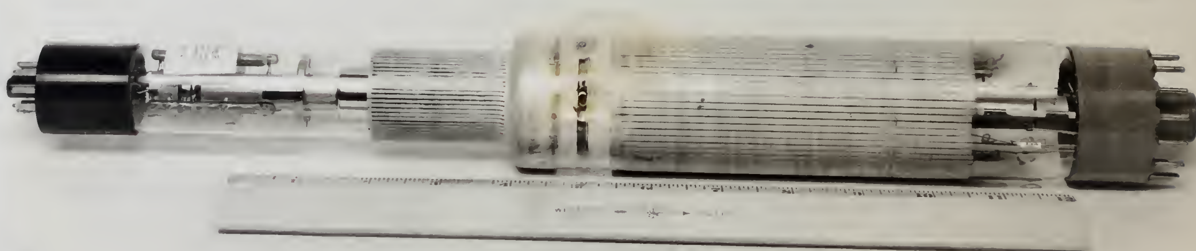
islands of charge on the surface. Normally information is written on with one electron beam and removed with another, although one gun sometimes performs both functions or the pattern is generated by light through photoemission.

2. The Graphechon.

In the Teleran system of air traffic control (Ewing, 2) the need for PPI to television scan conversion and for picture storage became evident. Methods originally tried were:(a) to pick up the afterglow of a P7 phosphor with a standard image orthicon and (b) to pick up the initial flash of a cathode ray tube without afterglow in a special high capacity image orthicon (Forgue, 7). Both of the above schemes require high brightness cathode ray tubes and an optical system which is unnecessary because light is only a link between two electrical signals. The Graphechon performs an all electronic conversion. The name is derived from the Greek words "graphe" (to write) and "echo" (to keep or to hold). Two independent guns at opposite ends of the tube, Fig. 1, are separated by a thin magnesium flouride target of high capacity. Electron bombardment-induced conduction in the target material due to the high voltage writing beam gives high sensitivity. A low voltage reading beam scans the target at the standard television rate of 525 lines, 30 frames per second, 2 to 1 interlace; this charge removal slowly erases the picture and generates the output signal.

3. Applications:

Primarily the Graphechon is used as a scan conversion device



The Graphechon

such as from plan position indication to television indication or changing from one television frame rate to another. In addition it is used as a storage device which can present information continuously for controllable periods of time (up to about 1 minute) after an event has occurred.

A few applications will be listed and the chief advantage gained through use of the Graphechon will be indicated in each case.

In the Teleran air traffic control system the main advantage of the Graphecon is storage which permits time-division multiplex transmission of the television pictures which have been developed for various altitude layers. Conversion of radar to television presentation is of nearly equal importance in this case.

For G. C. A. (ground controlled approach) an elongated trace, produced by storage of the echo, permits the controller to estimate the path of the approaching aircraft more accurately. Because of the brilliant picture produced by the television kinescope, the indicator can be remotely installed in the airport control tower where the ambient light level is high.

In the V. G. bright tube display and for pictorial display of sonar information a great advantage is gained in signal to noise ratio through noise integration, i. e. repeated echoes cause complete storage on the target whereas random noise does not.

Data transmission between ships uses less bandwidth when a television scan replaces a PPI scan; here the Graphecon is used purely for scan conversion.

In the target designator application color coding of elevation angle information from several radars is achieved through use of three Graphechons, one in each primary color channel, and optical mixing of their outputs to give a three dimensional display.

No use has as yet been made of the Graphechon in digital computers but its storage capacity of 300,000 elements offers interesting possibilities. The Graphechon has not been used commercially although it might be applied to such functions as inspection of fast moving products or in editing of television programs. A deterrent in this direction may be the high cost of the tube ($600) and associated equipment.

CHAPTER II

DESCRIPTION OF THE TUBE

1. Physical Configuration:

As originally designed the Graphechon was a single ended tube. The writing gun was mounted perpendicular to the target, in order to avoid keystone correction for radial deflection patterns while the reading gun was mounted at an angle of 30 degrees, as in the iconoscope, for which the keystone correction has been solved. Dimensions of this tube are 17 inches in length by 5 inches diameter, exclusive of reading gun projection.

An even smaller tube has been built, utilizing electrostatic deflection, with a length of 13 inches and a diameter of 4 inches.

The double ended tube shown in Figs. 1 and 2 is the model of the Graphechon in widest use at present and is the one to be described in this paper. It is 17 inches in length, the writing end is 1 3/8 inches in diameter and has an eight pin base mount while the reading end is 2 inches in diameter and has a fourteen pin base mount. The target is mounted about one inch from the shoulder in the larger section and a contact button to the backing plate is brought out at this point. Two external silver coatings with longitudinal gaps can be seen in Fig. 1; these act as faraday shields for the electron beams. In addition the capacitance from the inner aquadag to this shield on the reading side serves to confine the 30 Mc. grid modulation to the desired

region, i. e. prevent it from reaching the target plate by any other means than through the electron beam.

2. Electron Guns:

The writing gun is a standard one used in the type 12 DP7 kinescope and has adequate resolution at its designed voltage of 6 to 12 kilovolts.

The reading gun is a standard iconoscope gun which is designed to work at 800 to 1000 volts.

3. The Target:

A cross section of the target is shown in the insert of Fig. 2. This sketch is not to scale since the wire diameter of the 500 mesh screen is approximately 200 times the thickness of the aluminum film. The target will be described in some detail since it is the heart of the Graphechon and the construction of it involves some novel techniques.

Woven wire copper screening cannot be made finer than 200 mesh so that a new method had to be developed for making a fine mesh supporting screen for the target which would not limit resolution. This requirement results from the fact that the writing beam must penetrate through the target in a double ended tube. A photographic process using engravers enamel on a glass plate was first tried but did not produce screens which were sufficiently uniform. The glass master process is in use at present (Law, 12). An optically flat glass plate with ruled and etched grooves corresponding to the wires of the screen to be produced is sputtered with Pd. (palladium). Using a thin piece of

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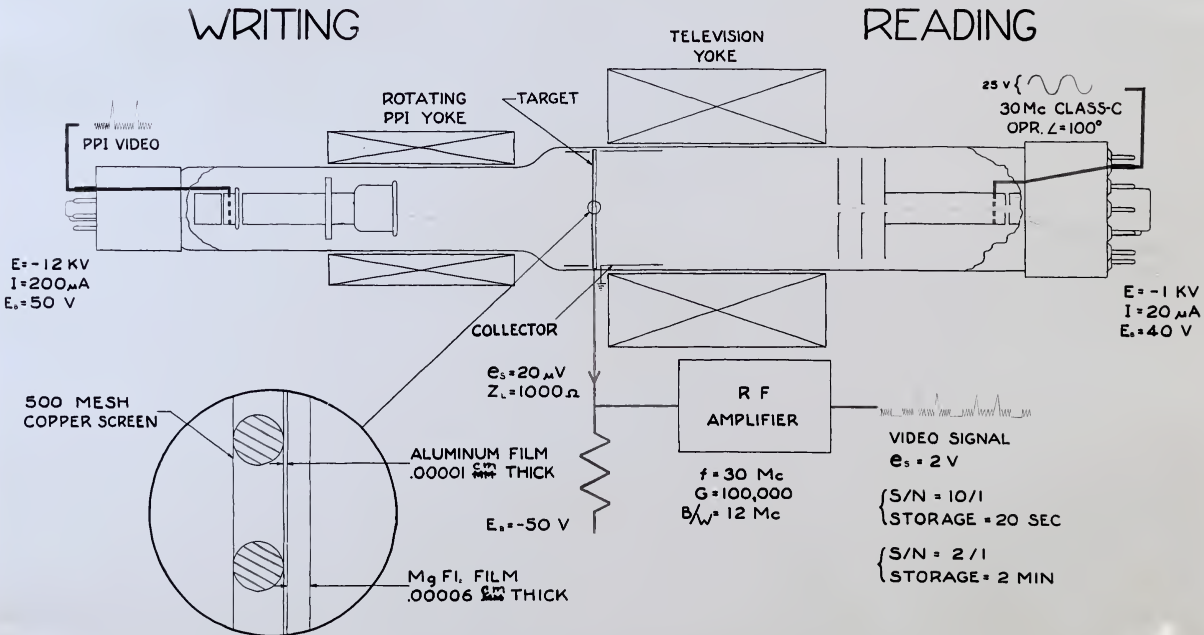
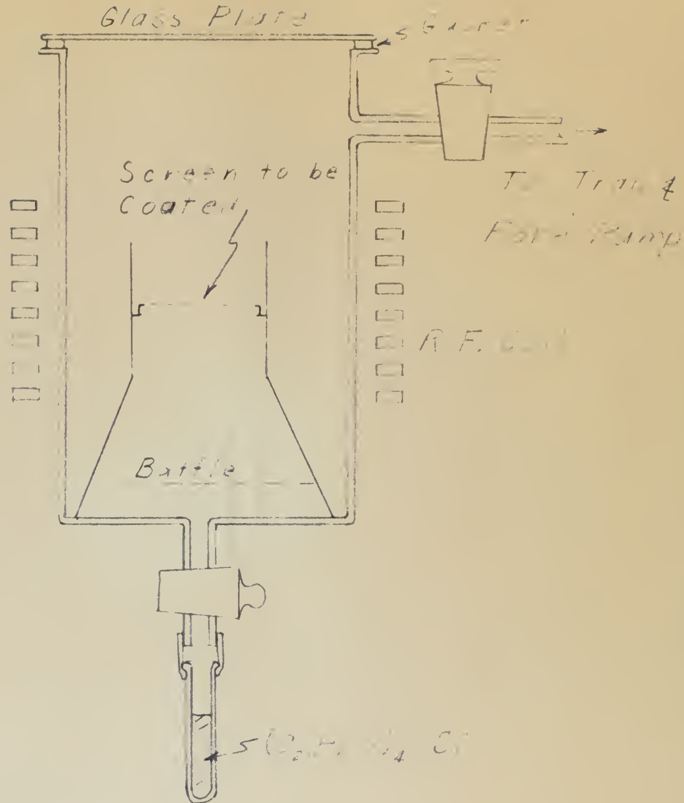

WRITING
READING
TELEVISION YOKE
ROTATING PPI YOKE
TARGET
PPI VIDEO
25 v
30 Mc CLASS-C
OPR. ∠=100°
E=-12 KV
I=200μA
E₀=50 V
E=-1 KV
I=20μA
E₀=40 V
COLLECTOR
e_s=20μV
Z_L=1000Ω
500 MESH COPPER SCREEN
ALUMINUM FILM .00001 cm THICK
E_0=-50 V
Mg Fl₂ FILM .00006 cm THICK
R F AMPLIFIER
f=30 Mc
G=100,000
B/W=12 Mc
VIDEO SIGNAL
e_s=2 V
S/N=10/1
STORAGE=20 SEC
S/N=2/1
STORAGE=2 MIN

rubber and with water as a lubricant the Pd. is rubbed off the surface of the glass while the Pd. in the grooves remains. Copper is then plated on the Pd. in the grooves to form the desired screen which is then peeled off the glass. Etched lines in the glass are 0.1 to 0.3 mils wide; the resulting plated wires are as much as twice this width. Screens have been made in production of 200, 500 and 1000 mesh with transmissions of 75%, 60% and 40% respectively. For mounting, the screen is tightened on a ring (which has a lower coefficient of expansion) by heating to 800 or 900 degrees centigrade in a rough vacuum and observing the screen surface during the heat. Although it is a crystalline substance the copper appears to possess a surface tension at a point below its melting point and thus tightens in the manner of an amorphous substance such as glass.

The screen thus produced is coated with an organic film and an aluminum film 0.1 micron thick is evaporated on this surface. An insulating film 0.6 microns thick is deposited on the aluminum (Law, 11). One method for producing the insulating layer is the evaporation of ethyl silicate (more exactly tetraethyl orthosilicate -- $(C_2H_5O_4)Si$) in a rough vacuum at room temperature onto the target surface which is heated to a temperature of about 800 degrees centigrade by radio frequency induction, see Fig. 3. The vapor decomposes on striking the hot surface and forms amorphous silica. Progress of the deposition may be followed by observing the thin film interference colors. The film shrinks during formation. This could be due to (a) surface



Apparatus for Deposition of
Silica on Metal
Fig. 5

tension or (b) hydrated silica forming during decomposition and being dehydrated as heating continues, thus:

$$
\begin{array}{lclcl}
(C_2H_5O)_4\,Si & \longrightarrow & 2(C_2H_5O\,C_2H_5) & + & SiO_2 \\
 & & \downarrow & & \big\downarrow \\
 & & 2(2C_2H_4 + H_2O) & & \\
 & & \qquad\quad \downarrow & & \\
 & & \qquad\quad SiO_2 \cdot nH_2O & &
\end{array}
$$

The film will readily withstand an electric stress of four million volts per centimeter. This process could be used in the production of small, high capacity condensers.

CHAPTER III

PRINCIPLES OF OPERATION

1. Secondary Electron Radiation:

Because secondary electron radiation is a prime factor in target operation, a few important properties will be enumerated. The term secondary electron radiation rather than secondary emission is used so that the latter term may be applied to the low velocity components of secondary radiation (Harries, 15). Characteristic energy distribution of secondary radiation is illustrated in Fig. 4a. The general shape of this curve applies to all substances which are subject to electron bombardment. Peak A of Fig. 4a represents primary electrons which have been elastically reflected; peak B represents emitted or true secondary electrons.

The intensity of secondary radiation varies as the cosine of the angle from the normal and is virtually independent of the angle of impact of the primary beam. However for insulators the coefficient of total secondary radiation depends on the impact angle of the primary beam.

The coefficient of total seconary radiation as a function of primary impact energy is shown in Fig. 4b. This curve is typical of most materials; metals having a maximum at 400 to 600 volts of primary beam energy and insulators at a somewhat higher value. Points A and B were the coefficient is unity

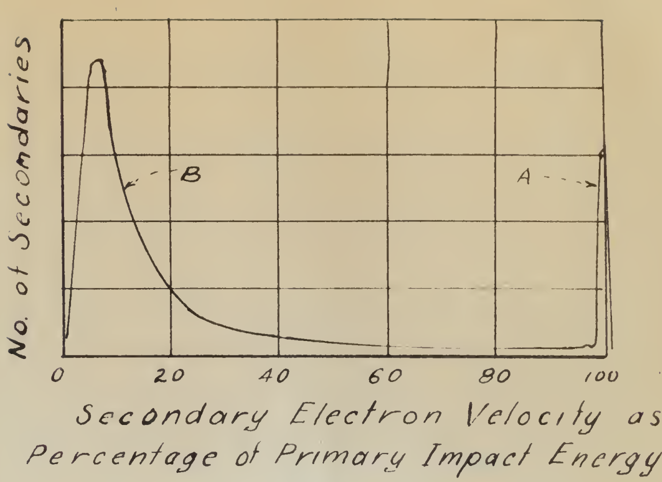


Fig. 4 a

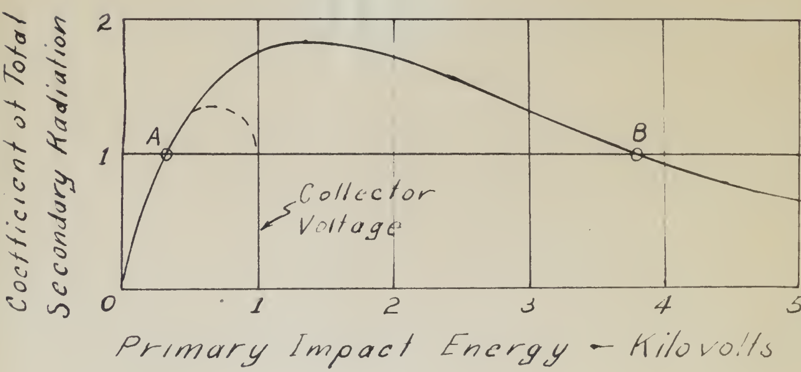


Fig. 4b

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are called the first and second crossover points respectively. They are of particular interest in determining the equilibrium conditions of an insulated electrode or insulator in a vacuum tube.

Emission time of secondary electrons is less than 10^{-9} seconds and therefore is no limitation in present applications.

2. Equilibrium Conditions:

Equilibrium condition for an insulated surface under electron bombardment is necessarily that at which the rate of electrons leaving the surface equals the rate of those arriving. The only method for departure is by secondary radiation. If the energy of the primary beam is below the first crossover point, the surface tends to go negative down to the gun cathode potential. This happens because fewer electrons leave the surface than arrive until the surface is sufficiently negative to repel the beam completely. The Orthicon (Rose, 5) and Selectron (Rajchman, 16) make use of this point.

If the primary beam energy is between the first and second crossover points, then more electrons leave than arrive causing the surface to go more positive. When the collecting field is maintained as in a voltage saturated or temperature limited diode, the positive surface accelerates the succeeding electrons so that they strike at higher velocities and thereby produce fewer secondaries. The upper limit to this process is the voltage of the secondary crossover point at which no further potential changes occur due to the equality of arriving and departing electrons.

If the collecting field is not maintained and the collector voltage fixed between the first and second crossover points then the surface comes to equilibrium at a potential near that of the collector electrode, see dotted line Fig. 4b. At this value the faster secondaries (reflected), in an amount equal to the beam, are collected and the slower ones (emitted) turn around and go back to the insulator surface. This is an equilibrium point because any increase in surface potential causes it to collect more of the slow secondaries and it is driven negative; the reverse happens when it goes negative. This is the condition of the reading beam in the Graphechon.

If the primary beam voltage is above the seoncd crossover value, then more electrons arrive than leave and the surface goes negative, the limit being the second crossover point. This process is not affected by collector voltage. The writing gun in the Graphechon is operated well above the second crossover point.

3. Conduction Effect:

A new conduction effect has been found when thin insulating films are penetrated by a high velocity electron beam (Pensak, 3). The value of the induced current can be as much as one hundred times that of the bombarding beam current. The insulation recovers completely after the penetrating beam is removed, much in the manner of a gas discharge. By calculation of the depth of penetration from the Thomson-Whiddington law, which indicates that penetration varies with the square of the beam voltage,

and by use of data gathered by Terrill, which indicates that beam current falls off exponentially with penetration, Pensak has shown that the conduction current is proportional to the energy absorbed in the film. Thus for beam energies greater than that required for penetration the conduction current falls off; also, for a double sided target, secondary radiation from the far side of the target will affect the total current. It has been shown that the conduction current is proportional to the voltage gradient across the film and does not critically depend on the material nor crystal structure. Materials tested thus far are silica, magnesium flouride, aluminum oxide, barium borate and mica. Thicknesses used were 2500 to 15000 Angstroms with potential gradients of one million to four million volts per centimeter.

4. Equivalent Circuits:

Two equivalent circuits which are helpful in explaining the operation of the Graphechon are shown in Fig. 5 (R. C. A., 9). These circuits are not to be considered exact for purposes of quantitative calculations of tube characteristics but merely to assist in a qualitative explanation. Definitions of the symbols used in Fig. 5 are listed below; all voltages are with reference to the aquadag coating which is grounded.

C_c - target film to collector capacitance per unit area (varies from canter to periphery).

C_F - capacitance per unit area, front to back of film.

E_c - target film to collector potential at any point on film.

E_L- output voltage.

E_R- reading beam accelerating voltage (1 Kv.).

E_T- target back plate voltage (about -60v.).

E_W- writing beam accelerating voltage (10 Kv.).

I_F- total film current = $I_K + I_W$(for negative E_T).

I_K- conduction current through film under bombardment.

I_R- reading beam current.

I_W- writing beam current.

I'_W- amount of I_W intercepted by magnesium flouride film (approximately equal to I_W if $R_{AL} \gg R_{MF}$).

R_c- effective a.c. film to collector resistance for a differential charge on the film surface. It is the slope of the E_c vs. I_c curve of Fig. 6a.

R_F- film effective resistance due to the release of electrons in the film by impact of the writing beam.

R_L- load impedance.

R_R- effective reading gun resistance (about 1 megohm).

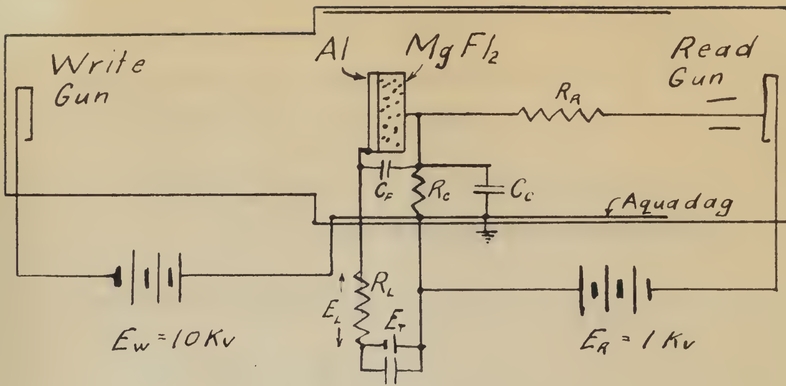
R_W- effective writing beam resistance; equal to the parallel combination of R_{AL} and R_{MF}.

R_{AL}- measure of I_W intercepted by the aluminum film.

R_{MF}- measure of I_W intercepted by the magnesium fluoride film.

5. Writing:

When the writing beam strikes the target, it is rapidly discharged down toward back plate potential from the equilibrium condition at collector voltage. Secondary radiation from the reading side of the target is in the same direction as the

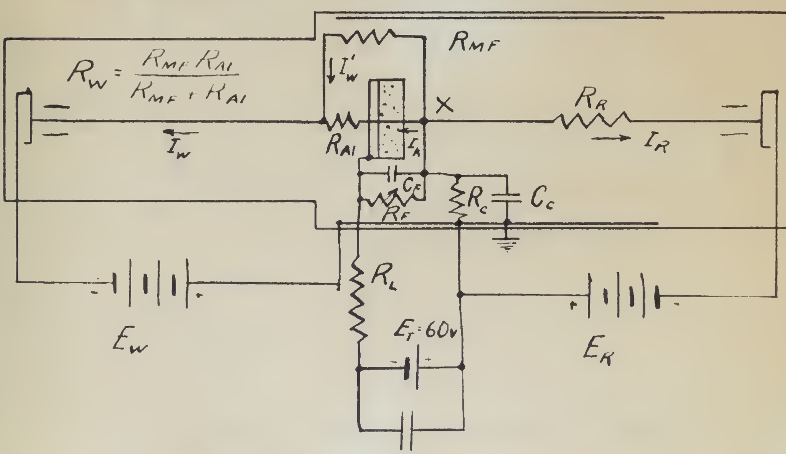


(a) Reading Beam Only

$R_R > R_W \gg R_L$

$R_c \gg R_F$

$R_{Al} \gg R_{MF}$



(b) Both Beams

Graphechon Equivalent Circuits

Fig. 5

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conduction current if a negative back plate potential is used, and it will aid in discharge. This discharge is equivalent to a jump from u to v on the diode characteristics of Fig. 6b. The charge on the film is defined thus:

$Q_F = E_F C_F$, where Q_F is the charge per unit area; E_F and C_F are as defined in section 4 above.

The rate of discharge is

$$\frac{dE_F}{dt} = -\frac{dE_c}{dt} = \frac{1}{C_F}\frac{dQ_F}{dt} = -\frac{I_F}{C_F}$$

but $I_F = I_W + I_K = K_1 + K_2E_F$, where the K's are constants. Conduction current is proportional to the voltage gradient across the film as explained in paragraph 3 above.

$$\frac{dE_F}{dt} = -\frac{1}{C_F}(K_1 + K_2E_F) = -(K_3 + K_4E_F).$$

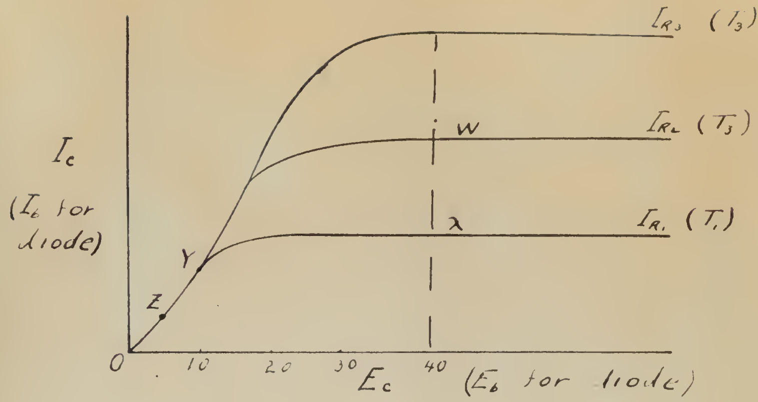
Separating and integrating

$$\int_{E_T}^{E_F}\frac{dE_F}{K_3 + K_4E_F} = -\int_0^t dt$$

$$\frac{1}{K_4}\log_\varepsilon(K_4E_F + K_3)\Big|_{E_T}^{E_F} = -t$$

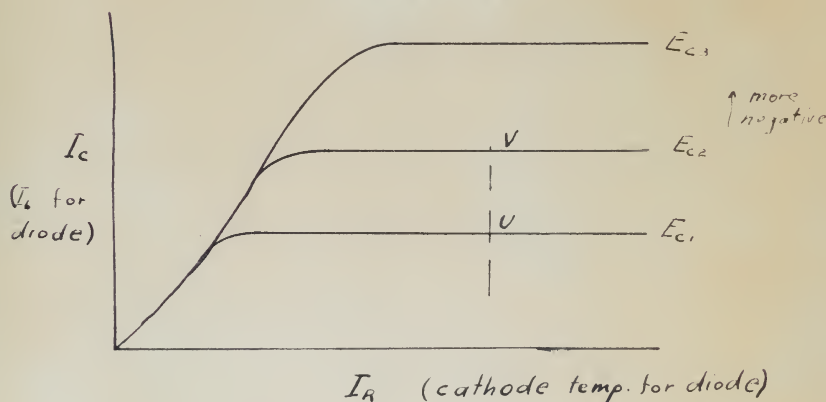
$$E_F = \frac{K_3}{K_4}(e^{-K_4t} - 1) + E_T e^{-K_4t}$$

Once laid down the charge will remain until changed by the reading beam. The transverse insulation of the target surface is so high that charge patterns have been stored on



(a) Collector Current vs Collector Volts

(Similar to temperature saturated diode)



(b) Collector Current vs Primary Current

(Similar to voltage saturated diode)

Fig. 6

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the targets of inoperative tubes for several weeks.

6. Reading:

With the writing beam off, the equivalent circuit of Fig. 5a applies. Point X is negatively charged and any change of charge of C_F flows through R_L producing the video signal, $E_L = R_L I_R(r - 1)$; where r is the coefficient of total secondary radiation. From the diode characteristics of Fig. 6a it is seen that when E_c is greater than 10 volts any increase in signal must come from an increase of reading beam current (x to w) because the collector current is voltage saturated between x and y. E_L will be constant in the region xy and will thus give a black and white picture. In the region yzo there is a change in the collector current corresponding to a change in collector voltage; therefore there can be half tones. Thus: $I_L = I_{CF} = I_R - I_c$ where I_{CF} = reading beam charging current; I_R - reading beam current, which also equals K_5 ; I_c = secondary radiation going to the collector.

In the region xy; $I_c = K_6$

$$I_L = K_5 - K_6 \quad \text{and} \quad \frac{dI_L}{dE_c} = 0 . \quad \text{No half tones.}$$

In the region yzo; $I_L = K_7 E_c$

$$I_L = K_5 - K_7 E_c \quad \text{and} \quad \frac{dI_L}{dE_c} = - K_7 . \quad \text{Half tones.}$$

Because the reading beam is not much affected by target potential, the rate of charge is a constant/

$$\frac{dE_c}{dt} = \frac{1}{C_F}\frac{dQ_F}{dt} = \frac{I_R}{C_F}(r — 1)$$

7. Viewing Time:

The saturation of secondary radiation is used to obtain many television pictures of the writing pattern. The amount of secondary radiation is proportional to the reading beam current, as from w to x in Fig. 6a, to reduce the amount of charge removed each scan. However, this also decreases the signal output and the lower limit is the signal to noise ratio of the vedeo amplifier.

Quantitative evaluation of the viewing time may be found by equating the initial negative target potential due to the writing beam, E_{co}, to the total decrease in this potential through reading beam charging. The latter quantity is:

$\frac{T_s}{n}\frac{dE_c}{dt}$ where T_s is the viewing time and n is the number of target elements by television standards.

Then

$$E_{co} = \frac{T_s}{n}\frac{dE_c}{dt}$$

but

$\frac{dE_c}{dt} = \frac{1}{C_F} I_R (r — 1)$ from paragraph 6 above.

Therefore

$T_s = \frac{nC_F E_{co}}{I_R(r — 1)} = \frac{C_T E_{co}}{I_R(r — 1)}$ where C_T = total target capacity = nC_F

For a parallel plate capacitor,

$C_T = 0.0885 \frac{kA}{d}$ micromicrofarads

where k - dielectric constant of film

A - area of target

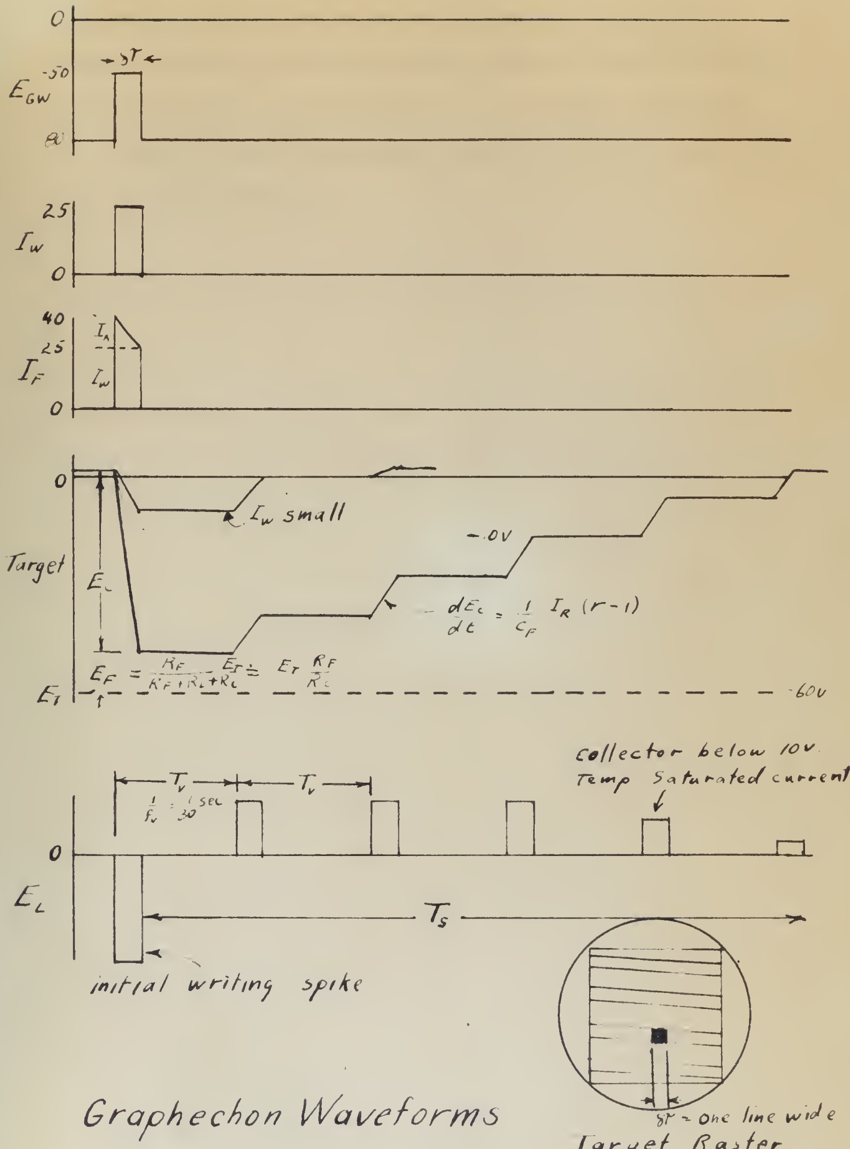
d - thickness of target (0.6 micron)

For a large I_W, R_F is very small and E_{co} is approximately equal to E_T; then

$$T_S = \frac{8.85 \times 10^{-14} kA\, E_T}{I_R (r - 1) d}$$

Thus it can be seen that viewing time is directly proportional to the area of the target and inversely proportional to the reading beam current. It might at first appear that viewing time could be increased by using a thinner target, but if this is done the maximum back plate potential must be reduced proportionately to prevent target breakdown. High dielectric constant and uniform target thickness are seen to be important for maximum viewing time. It is furthermore important, in operation, to keep the potential gradient as high as possible in order to increase viewing time and writing speed. The very long static storage time of the target, which is determined by the leakage resistance of the magnesium fluoride, can be used to advantage in operation to yield an exceptionally long viewing time where it is not necessary to read constantly at a television rate; e. g. the time sharing of the Teleran system (Ewing, 2).

Waveforms of several voltages and currents, as derived from the above analysis, are shown in Fig. 7. This sequence depicts



Graphechon Waveforms

Fig. 7.

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the writing on of a single dot and its removal in about five scans. Note that the output voltage pulses, E_L, remain constant until the target has been charged up to -10 volts. The effect of reducing writing beam current is indicated by the upper curve for the target voltage, E_T.

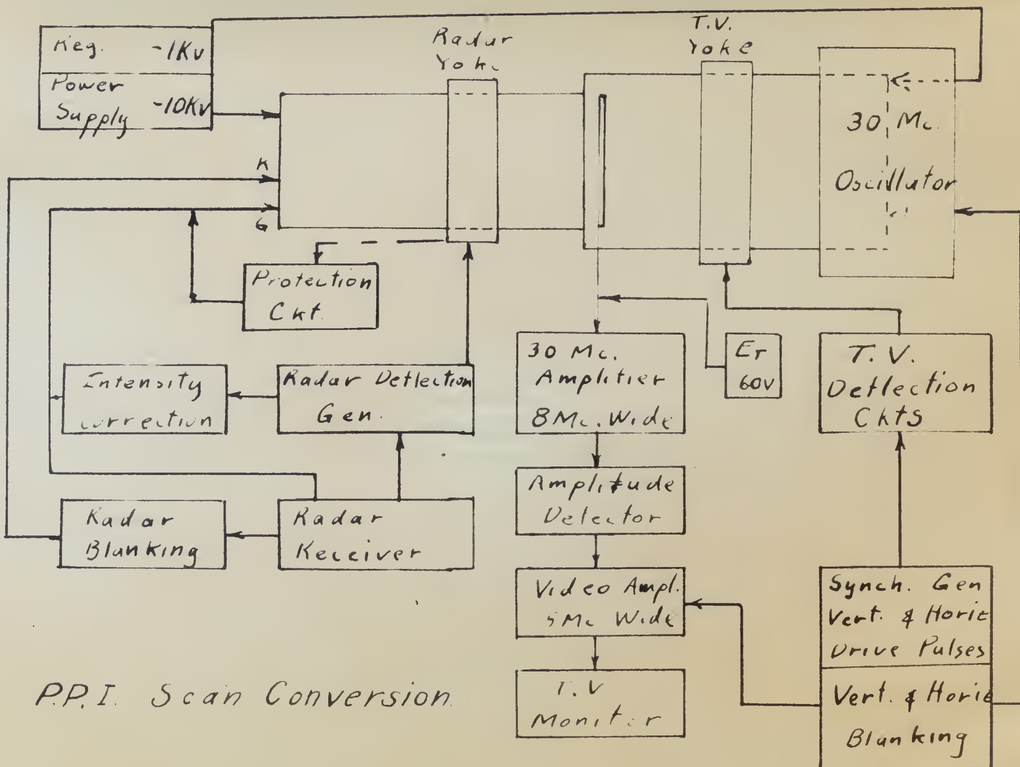
CHAPTER IV

PRACTICAL OPERATION

1. PPI Scan Conversion:

The Graphechon finds its widest application at present in the plan position indication to television scan conversion. The block diagram, Fig. 8, applies in its essentials to any of the conversion systems, VG bright tube display, GCA, target designator, etc. A range intensity correction is necessary in order to reduce the negative charge density in the center of the target which is mainly due to the overlapping lines and is enhanced by the non-uniform collecting field from center to periphery. A negative area would suppress secondary radiation and make signals appear stronger near the center of the display. A target protection circuit is required to cut off the writing beam if the yoke stops rotation since this high velocity beam would soon burn a hole in the target if left in one position. The safety circuit can be a simple generator geared to the yoke and operating a relay which in turn controls the writing video amplifier or the high voltage supply.

The writing beam produces much higher video pulses than the reading beam; $E_L = I_w R_L$ may be 1000 times the reading signal. Although it is of opposite polarity to the reading signal (see Fig. 7), it is impractical to clip it because small variations of clipper tubes would cause trouble at these low levels, mainly in blocking of the video amplifier. Frequency



P.P.I. Scan Conversion

Fig. 8

separation of writing and reading information is used as described in section 2 below. The reading beam is blanked during retrace time since it would produce black lines on the raster if unblanked and would in addition reduce the viewing time.

2. 30 Mc. Oscillator and Amplifier:

The first grid of the reading gun is modulated at 30 Mc. class C in order that writing and reading video information can be separated at the output of the target. The oscillator is a 6C4 tube crystal controlled at 15 Mc. operating into a 6J6 doubler and blanking tube shown to the left in the schematic diagram Fig. 9. The entire oscillator is built on an annular chassis which fits in a cylindrical shield can over the reading end socket, see Fig. 10. Since the 30 Mc. signal at the reading grid is about 10 volts and the output at the target is of the order of 10 microvolts an attenuation of 120 db. is required. A grounded external faraday shield on the tube surface is used to prevent direct leakage and also prevent external electrostatic fields from deflecting the beam. Elaborate decoupling is employed for all leads into the oscillator shield which makes contact to the faraday shield; thus confining all the R.F., except that in the electron beam, to the surface and reading gun of the Graphechon. Since the d.c. component of the reading beam merely discharges the target with no useful output, the pulse angle had to be chosen to give the maximum

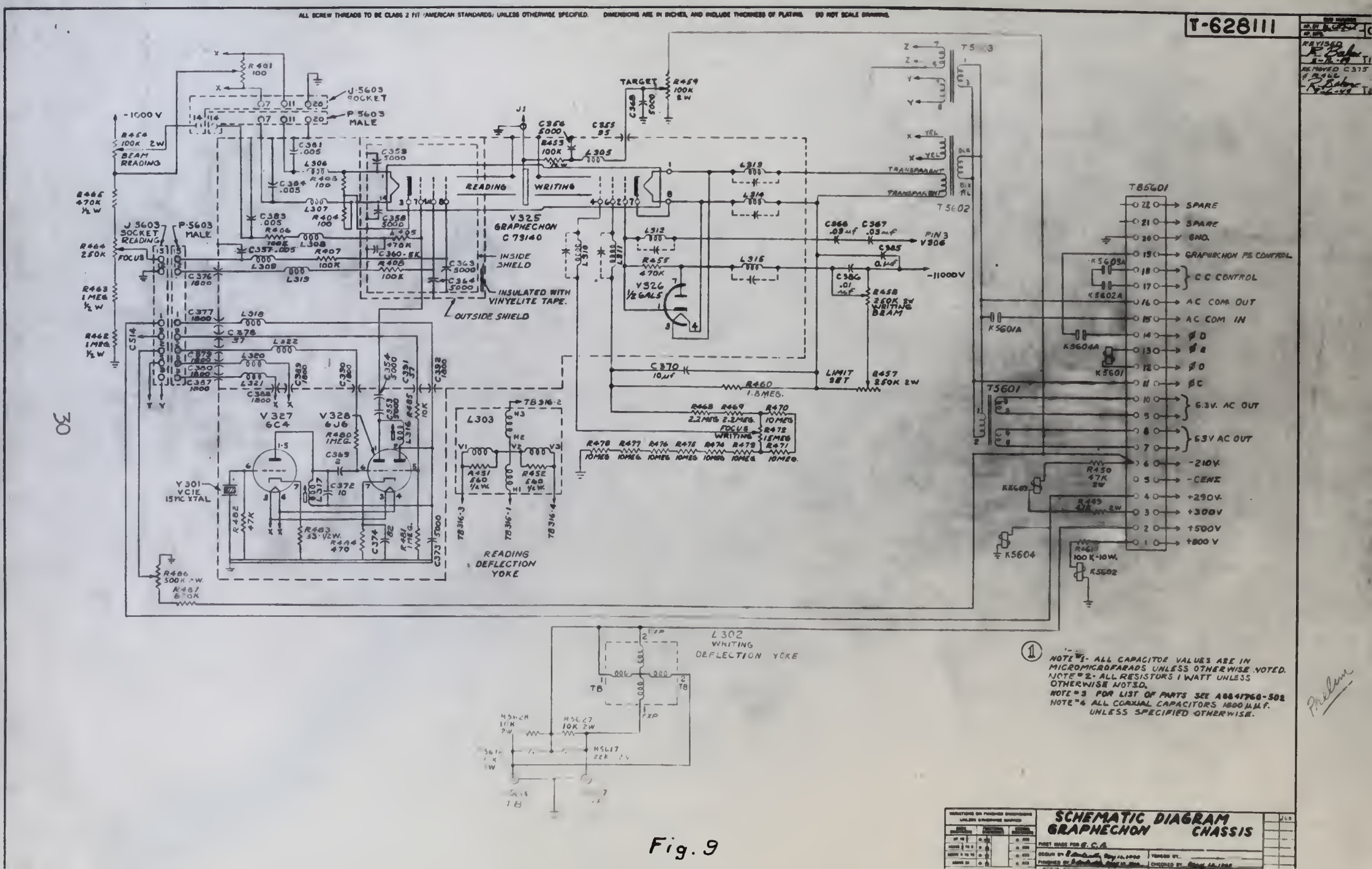

T-628111
ALL SCREW THREADS TO BE CLASS 2 FIT (AMERICAN STANDARDS) UNLESS OTHERWISE SPECIFIED. DIMENSIONS ARE IN INCHES, AND INCLUDE THICKNESS OF PLATING. DO NOT SCALE DRAWING.
V325 GRAPHECHON C 73140
READING
WRITING
INSIDE SHIELD
INSULATED WITH VINYELITE TAPE.
OUTSIDE SHIELD
V326 1/2 6AL5
V327 6C4
V328 6J6
Y301 VC1E 15MC XTAL
READING DEFLECTION YOKE
L302 WRITING DEFLECTION YOKE
J5603 SOCKET READING
P5603 MALE
J-5603 SOCKET
P 5603 MALE
-1000 V
BEAM READING
FOCUS
TARGET
LIMIT SET
WRITING BEAM
PIN 3 V306
-11000V
TB5601
SPARE
SPARE
GND.
GRAPHECHON PS CONTROL
C C CONTROL
AC COM OUT
AC COM IN
ØD
ØB
ØD
ØC
6.3V. AC OUT
6.3V AC OUT
-210V.
-CENT
+290V.
+300V
+500V
+800 V
NOTE #1- ALL CAPACITOR VALUES ARE IN MICROMICROFARADS UNLESS OTHERWISE NOTED.
NOTE #2- ALL RESISTORS 1 WATT UNLESS OTHERWISE NOTED.
NOTE #3 FOR LIST OF PARTS SEE A8641760-502
NOTE #4 ALL COAXIAL CAPACITORS 1800 µµf. UNLESS SPECIFIED OTHERWISE.
SCHEMATIC DIAGRAM GRAPHECHON CHASSIS
REVISED
REMOVED C375

Fig. 9

30 Mc. Oscillator

Fig. 10

ratio of 30 Mc. current to direct current. A one hundred degree conduction angle was chosen as the best compromise between storage efficiency and undesired R.F. leakage to the writing gun.

Target load resistance, R_L, is replaced by, Z_L, tuned to 30 Mc.; in this case an inductive T network with 1200 ohms across the input to the first tube, see Fig. 11. The amplifier must have 80 db. attenuation to the highest radar video frequencies in order to prevent cross talk between the beams. A conventional stagger tuned amplifier is used, with a gain of 110 db., a 10 Mc. bandwidth and a cathode follower video output; a schematic diagram is shown in Fig. 11. The ultimate factor determining viewing time, besides potential gradient and area of the target, is the noise factor of the 30 Mc. amplifier since this determines the minimum value of reading beam current which can be used to give a readable output. A low noise Wallman input circuit is used (Wallman, 17) and a noise factor of 4.2 db. has been obtained.

3. Video Narrow Banding:

Transmission of television broadcasts at the present R.M.A. standard requires a video frequency range of 30 to 4,000,000 c.p.s. It can be shown (Fink, 18) that the maximum video frequency is directly proportional to the frame repetition rate. Thus if the frame rate could be reduced from 30 to 20 c.p.s. the maximum video frequency transmitted could be reduced to 2.2 Mc. The Graphechon offers a means for doing this by making a television scan rate conversion from 30 to 20 c.p.s. at the sending end of

DIMENSIONS ARE IN INCHES, AND INCLUDE THICKNESS OF PLATING DO NOT SCALE DRAWING
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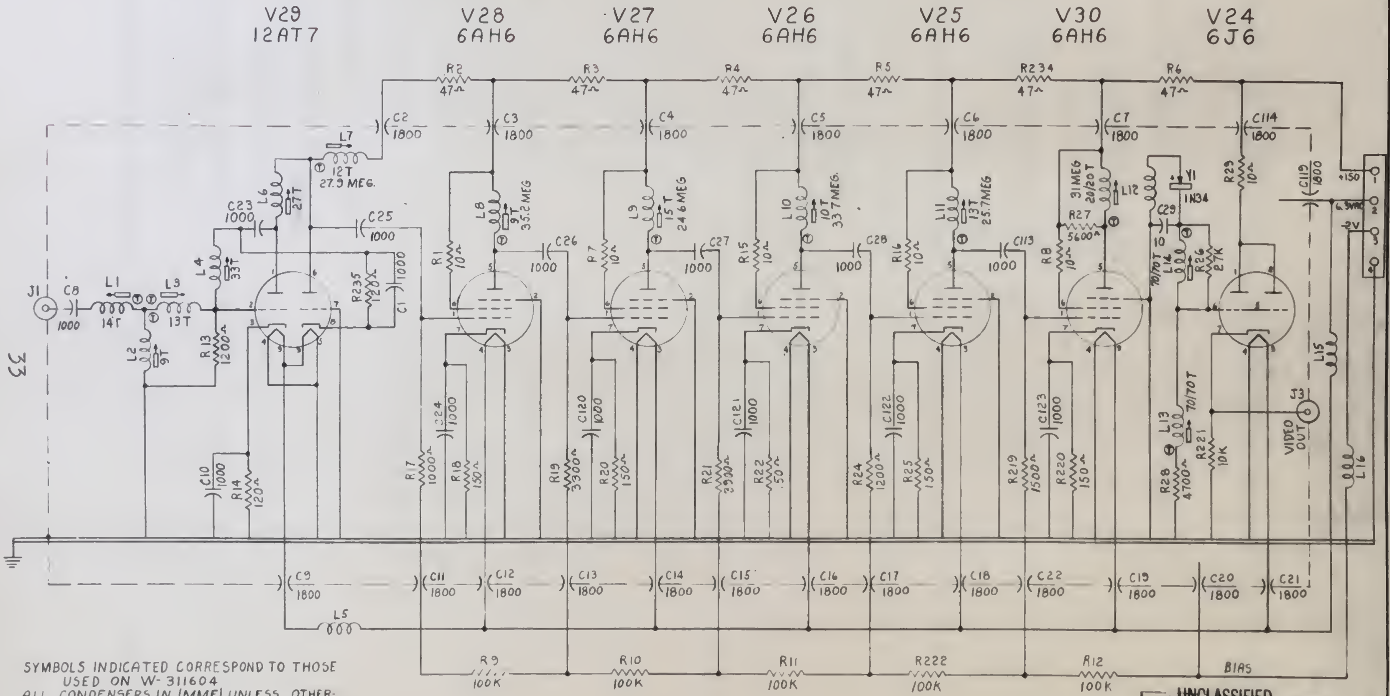

SYMBOLS INDICATED CORRESPOND TO THOSE USED ON W-311604
ALL CONDENSERS IN (MMF) UNLESS OTHERWISE NOTED
ALL RESISTORS ARE (½W) UNLESS OTHERWISE NOTED

UNCLASSIFIED

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Fig. 11

SCHEMATIC DIAGRAM
WIDE BAND R.F. AMPLIFIER

FIRST MADE FOR GRAPHECON CHASSIS

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P-740042

a video link and reconvert from 20 to 30 c.p.s. at the receiving end.

4. Miscellaneous Applications:

a) Single Trace Oscilloscope:

For this application the single ended electrostatic deflection Graphechon may be used. It will give a bright, complete trace of a single trace for viewing times up to several minutes. If the trace is not varied in intensity, grid modulation of the reading beam is not necessary and considerable simplification of the circuits results.

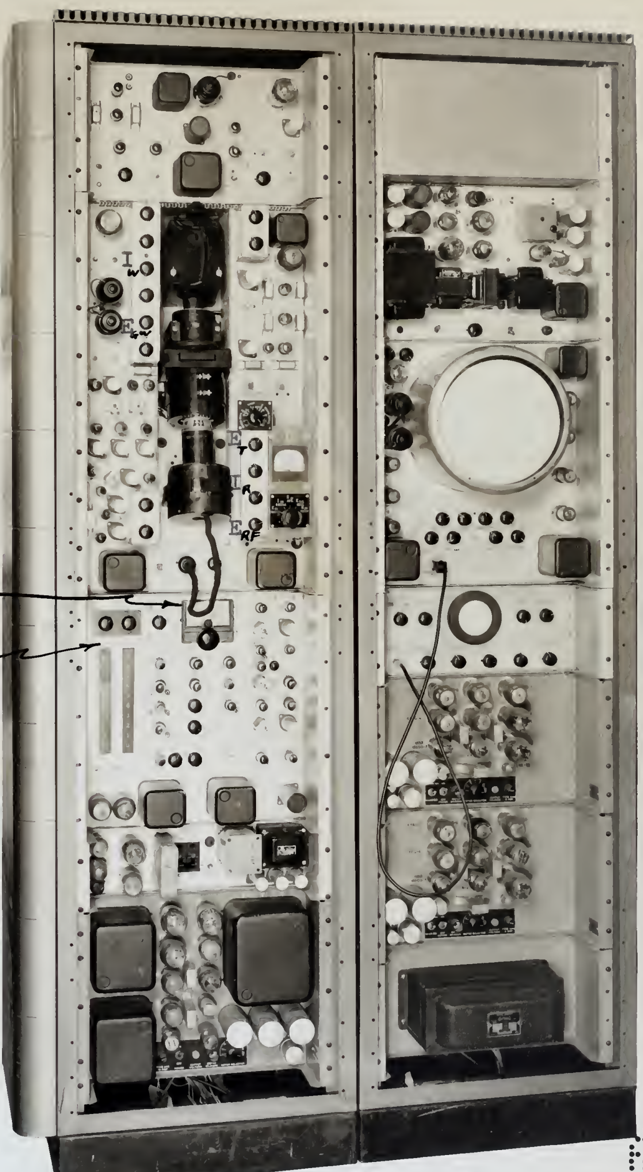
b) "Snap-Shot" Television Camera:

The output of an image orthicon camera (Rose, 6) can be used to modulate the writing gun of a Graphechon and furthermore the grid modulation can be gated on as desired to give a "snap-shot" picture of the scene before the orthicon. A modified form of this circuit has been proposed for quality control of tin plate production (Covely, 4). By gearing the frame rate to the rolls of a continuous strip mill, the surface of the metal may be inspected at convenient intervals. Flaws caused by particles stuck on the rolls indentify the offending roll by distance of recurrence.

5. Graphechon Test Set:

Quality control of the Graphechon requires the use of an accurate and flexible test set which simulates the actual field operating conditions. A television to television scan conversion is used for reasons of simplicity. The equipment shown

in Fig. 12, requires inputs for horizontal and vertical drive pulses, blanking and video which is usually obtained from a monoscope with a standard test pattern. A decade binary counter in conjunction with a phantastron delay circuit controls the input so that one to ninety nine fields may be written on the target at controllable intervals up to one minute. Thus, in order to simulate the video content of a radar pattern, 60 fields (one second) might be gated on at intervals of 10 seconds. All important parameters may be set to give desired viewing time, size of raster, beam currents, etc. The input to the Graphechon or its output may be viewed on an 18 inch monitor scope; schematic shown in Fig. 13. The R.F. oscillator and amplifier described in section 2 above are used in the test set to separate reading video from the writing video.



60405

GRAPHECHON TEST SET

Fig. 12

ALL SCREW THREADS TO BE CLASS 2 FIT (AMERICAN STANDARDS) UNLESS OTHERWISE SPECIFIED   DIMENSIONS ARE IN INCHES, AND INCLUDE THICKNESS OF PLATING   DO NOT SCALE DRAWING

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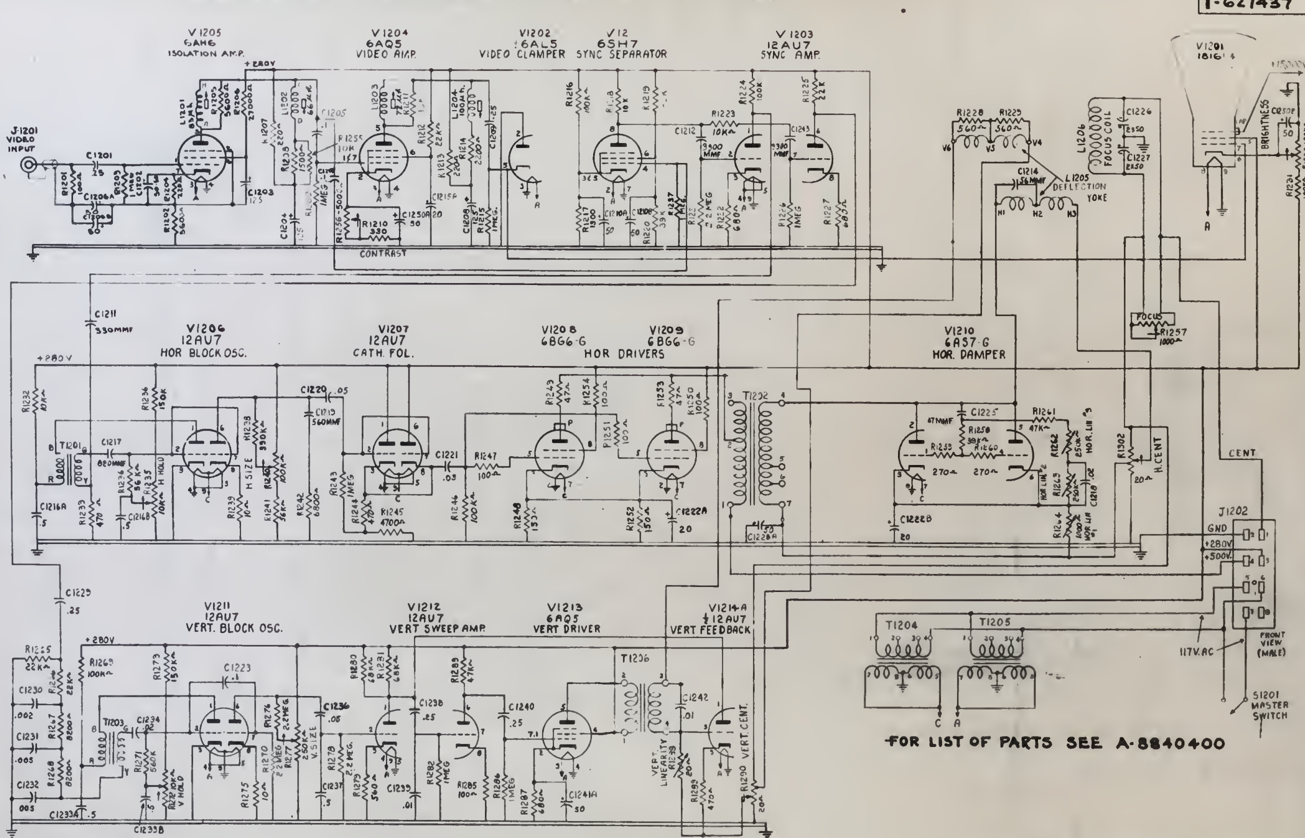

Fig. 13

SCHEMATIC DIAGRAM
FINAL DISPLAY

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T-627437

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CHAPTER V

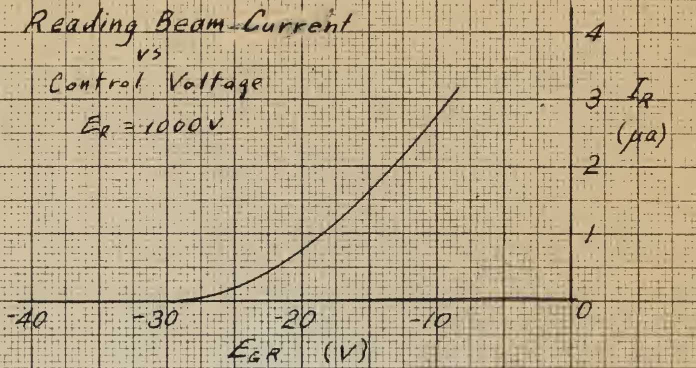
PERFORMANCE CHARACTERISTICS

1. Electron Beams and Target:

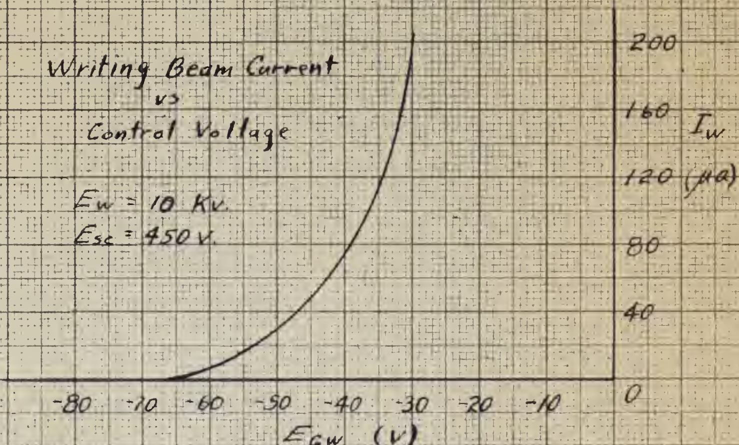
a) Reading beam accelerating voltage is normally 800 to 1000 volts. Beam current is 0.05 to 10 microamperes. Normal operation is with a bias of about - 34 volts and a signal of 10 volts peak to peak. Control characteristics are shown in Fig. 14(a).

b) Writing beam accelerating voltage must be greater than 5000 volts below which there is little conduction effect and secondary radiation is greater than unity, see Fig. 4(b). An upper limit for E_w is about 15 Kilovolts with optimum value about 9 kilovolts for maximum energy absorption in the 0.6 micron target. A great deal of heat is generated by the penetrating beam in the target and there is danger of burning a hole if the writing scan fails. Normal beam current is about 25 microamperes with a bias of - 80 volts and a 30 volt video signal. Control characteristics are shown in fig. 14(b).

c) Target back plate voltage can be 0 to -100 volts; usually about -50 or -60 volts. Maximum potential gradient can be obtained in operation by watching the monitor kinescope as the back plate is made more negative; when sudden white spots appear and spread on the target, breakdown has been reached. Posttive target voltages make writing less effective because secondary


Reading Beam Current
vs
Control Voltage
$E_R = 1000$ V
4
3
2
1
0
I_R
(μa)
-40
-30
-20
-10
E_{GR} (V)

(a)


Writing Beam Current
vs
Control Voltage
E_W = 10 Kv.
E_{SC} = 450 v.
200
160
120
80
40
0
I_W
(μa)
-80
-70
-60
-50
-40
-30
-20
-10
E_{GW} (v)

(b)

Fig. 14

emission opposes the conduction current.

2. Resolution and Writing Speed:

Writing speed is about 4000 feet per second or better than 9 million elements per second. Resolution is better than 300,000 picture elements but varies a great deal with viewing time. A coplanar grid effect is noted when strong writing signals are impressed. The beam produces a negative area on the reading side which suppresses secondary radiation around it for some distance. When viewed this shows as a white area outlined by a black border which decreases linearly with viewing time because it is a function of surface potential which decreases steadily when secondary radiation is saturated.

Shading is present due to the non-uniform radial field over the target surface. It shows as a white center shading to gray near the periphery. Future tubes may have a barrier grid installed directly in front of the target on the reading side to control the collecting field.

Half tones cannot be reproduced except for very short viewing times, since the target cannot be driven more than ten volts negative or the reading beam current increased to prevent secondary radiation saturation.

3. Noise Integration:

Due to the randomness of noise and the fact that target echoes are repeated signals, the Graphechon can be used as a noise integrator to give improved signal to noise ratio.

Rayleigh distribution of random noise envelope shows the peaks exceeding 1.5 times the r.m.s. value of noise only 10% of the time, twice the r.m.s. value 2% of the time and 3 times the r.m.s. value 0.01% of the time. The Graphechon picture has a grainy structure when E_{GW} is adjusted for complete storage of a signal 1.5 times the r.m.s. noise.

BIBLIOGRAPHY

1. Pensak, L. Picture storage tube. Electronics. 22:84-88, July 1949.

2. Ewing, D. H., and Smith, R.W.K. R.C.A. Review. 612, December 1947.

3. Pensak, L. Conductivity induced by electron bombardment in thin insulating films. Physical review. 75:472-478, February 1, 1949.

4. Covely, F.D. Application of the Graphechon to tin plate control. R.C.A. engineering memorandum No. 4041, 28 February 1949.

5. Rose, A., and Iams, H.A. The orthicon. R.C.A. Review. 186-199, October 1939.

6. Rose, A., Weimer, P.K., and Law, H.B. The image orthicon a sensitive television pick-up tube. Proceedings of the I.R.E. 424-432, July 1946.

7. Forgue, S.V. The storage orthicon and its application to Teleran. R.C.A. Review. 633, December 1947.

8. Zworykin, V.K., Morton, G.A., and Flory, L.E. Theory and performance of the iconoscope. Proceedings of the I.R.E. 25:;071-1092, August 1937.

9. R.C.A. air defense coordinator systems, contract NOrd 10076, final report of Princeton activities, June 30, 1948.

10. Pensak, L. The Graphechon, a picture storage tube. R.C.A. technical report, PTR-87, December 19, 1947.

11. Law, H.B. Formation of insulating layers by the thermal decomposition of ethyl silicate. R.C.A. engineering memorandum, PEM-67, March 25, 1947.

12. Law, H.B. Glass targets, fine mesh screens and monoscope targets for the image orthicon. R.C.A. laboratories technical report, PTR-25C, November 1, 1945.

13. Haeff, A. V. A memory tube. Electronics. 20:80-83, September 1947.

14. McConnell, R. A. Video storage by secondary emission from simple mosaics. Proceedings of the I.R.E. 35:1258-1264, November 1947.

15. Harries, J.H.O. Secondary electron radiation. Electronics. September 1944.

16. Rajchman, J.A. The Selectron. Mathematical tables and aids to computation. II:359-361, October 1947.

17. Wallman, H.A. A low noise amplifier. Proceedings of the I.R.E. 700-708, June 1948.

18. Fink, D.G. Principles of Television Engineering. McGraw-Hill, New York, 1947.